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Interface Definition Document for the Human Research Facility Refrigerated Centrifuge

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for the
Human Research Facility
Refrigerated Centrifuge

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Interface Definition Document
for the
Human Research Facility
Refrigerated Centrifuge

Prepared by: _____ _____

R. Yao
Project Engineer

Date

Approved: _____ _____

S. Campana
Project Manager

Date

Approved: _____ _____

J. McDonald
Manager, Hardware Development Section

Date

Prepared by:

Lockheed Martin Space Operations
Houston, Texas
for
National Aeronautics and Space Administration
Johnson Space Center

REVISION/CHANGE APPROVALS

Date	Change Number	Prepared by	Approved by:		
			Unit Manager	SR&QA Manager	Projects Manager

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ACRONYMS AND ABBREVIATIONS

ºC	Celsius
dm	decimeters
emf	electromagnetic force
EXPRESS	EXpedite the PRocessing of Experiments to Space Station
g	acceleration of gravity
HRD	Hardware Requirements Document
ICD	Interface Control Document
IDD	Interface Definition Document
kg	kilogram
min	minute
ml	milliliter
mm	millimeter
NSTS	National Space Transportation System
r	radius
RC	Refrigerated Centrifuge
RCF	Relative Centrifugal Force
RPM	Rotations per minute
sec	second

1.0 SCOPE

This Interface Definition Document (IDD) defines and controls the design interfaces between the Refrigerated Centrifuge (RC) for the end item users. This IDD and the user hardware unique Interface Control Document (ICD), which is developed from this IDD, are defined below.

1.1 DEFINITION OF INTERFACE DEFINITION DOCUMENT

A) Defines the interfaces that shall be provided by the RC for the items using the RC provided accommodations.

B) Defines and controls the constraints which shall be observed by the RC user and item developer.

C) Establishes commonality with respect to analytical approaches, analytical models, technical data, and definitions for integrated analysis by interfacing parties.

1.2 DEFINITION OF PAYLOAD UNIQUE INTERFACE CONTROL DOCUMENT

A) Describes the designed interfaces between the RC and the user hardware developed under the constraints of this IDD.

B) Defines and controls the constraints which shall be observed by the RC and user hardware.

C) Establishes commonality with respect to analytical approaches, analytical models, technical data, and definitions for integrated analysis by interfacing parties.

2.0 DOCUMENTATION

2.1 APPLICABLE DOCUMENTS

The following documents of the exact issue shown shall form a part of this document to the extent specified herein. In the event of conflict between the document referenced and the contents of this document, the content of this document shall be considered a superseding requirement.

Document Number	Rev.	Document Title
LS-71078-1		Hardware Requirements Document (HRD) for the Human Research Facility Refrigerated Centrifuge
SN-C-0005		NSTS Contamination Control Requirements
SSP 5700		Pressurized Payloads Interface Requirements Document

3.0 PHYSICAL INTERFACES

The Refrigerated Centrifuge is a modified version of the MILRO 22R, manufactured by Hettich. The physical containment of samples inside the centrifuge chamber shall be through rotating hardware (i.e., rotors, adapters, hanger, and buckets). Alternate physical containment of samples through user provided rotating hardware is allowed only if the rotating hardware is manufactured by Hettich for the use inside the type 1110-01 RC. If user-provided rotors are not from Hettich, then a written approval from RC manager is required pending a usage assessment indicating allowability and operating restrictions.

3.1 CENTRIFUGE CHAMBER AND SPINDLE

The centrifuge chamber is a bottomless stainless steel bowl. The bowl is set over a spindle that protrudes from a viscously mounted electric motor. The motor hood takes up the space between the motor and the bowl hole. The gap between the motor hood and the bowl is sealed with a rubber bellows that allows free movement of the motor. A rotor must be fastened to the spindle and produce no physical interference with the centrifuge chamber. See Figure 3.1-1 for chamber dimensions.

3.2 ROTOR

Samples may be contained in RC provided rotors. See Table 3.2-1 for a list of the rotors, adapters, and size of acceptable samples.

TABLE 3.2-1

Rotor	Adapter	Capacity in ml	Dimensions x L mm	Number of Samples
1016	1632	7 ml	12 x 100	18
1016	1635	12-15 ml	17 x 100	6
1016	1641	50 ml	29 x 115	3
1020	1131	2-5 ml	13 x 75	8
1020	1132	5.5 ml	15.3 x 75	8
1158	2023	0.5 ml	-	48
1158	2031	1.5 ml	-	48

3.3 TOOLS

Operation of the RC requires the use of one tool: the spanner release tool. The RC developer provides the spanner/release tool and it will be stowed within the internal stowage drawer.

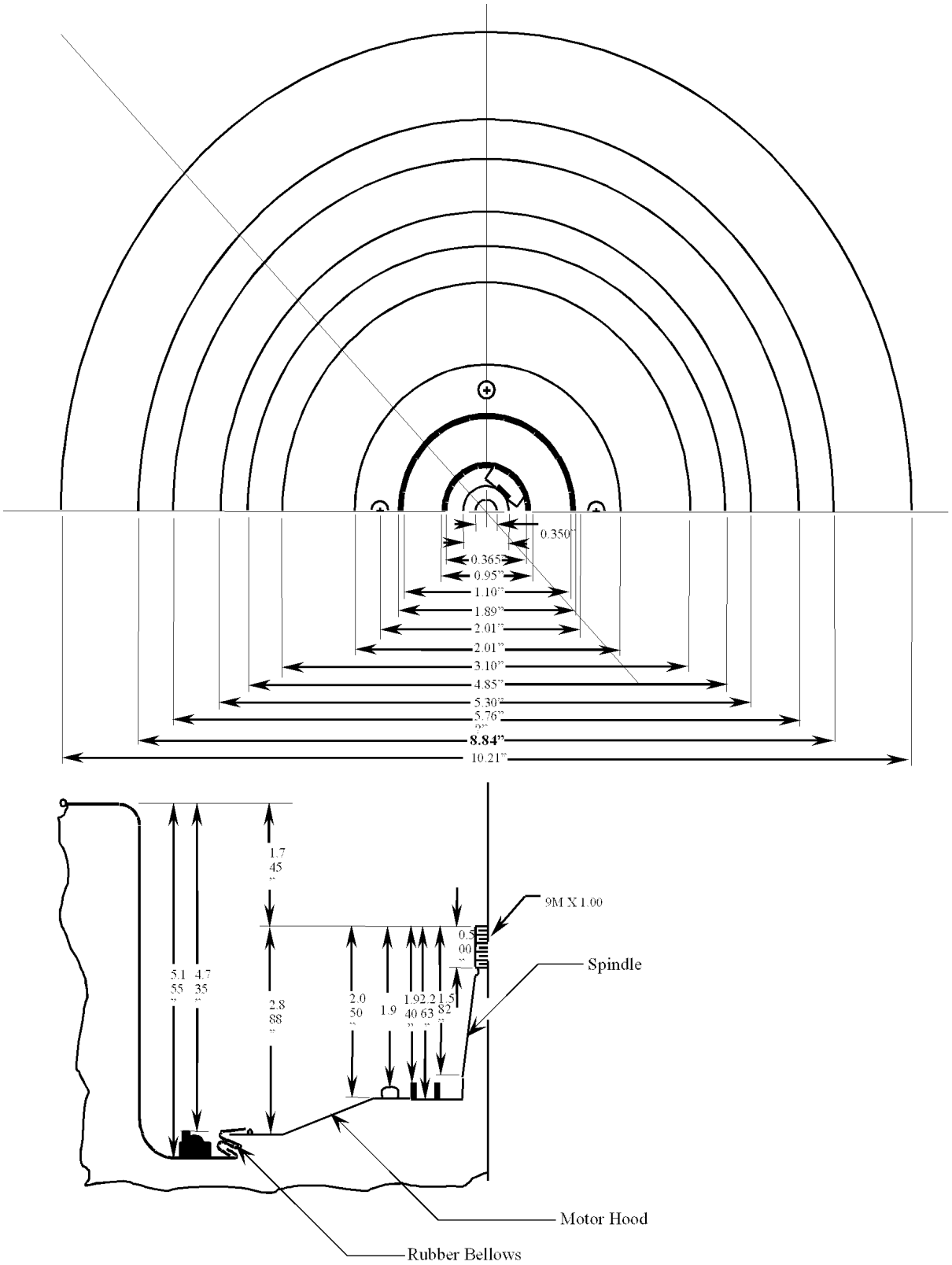


Figure 3.1-1. Chamber Dimensions

3.3.1 Fastening Rotor

The fastening of a rotor onto the spindle requires the use of the spanner release tool. The spanner release tool is a 5 mm hexagonal key with a plastic T-handle, which is used to turn the rotor's captive nut. An alternate 5 mm Allen wrench can also be used.

3.3.2 Emergency Door Opening

As a safety feature, the rotor chamber door cannot be opened without power. When loss of power occurs during operation, the door will be locked. In this situation, it is still possible to unlock the door with the spanner release tool; however, extreme caution should be taken during this operation. It is very important to check through the inspection window to make sure the rotor has stopped. Then insert the spanner release tool into the lock release hole located above the latch bar and push until the locking mechanism releases the locking tab. The door can then be opened by pressing down the latch bar lock and swiveling the latch bar upwards. An alternate 5 mm Allen wrench can also be used to perform the same task.

4.0 STRUCTURAL INTERFACES

4.1 CENTRIFUGAL ACCELERATION (RCF OR Gs)

The RC requires an installed rotor on the spindle in the chamber to operate. Centrifugal acceleration experienced by the rotor will depend on the rotational speed (RPM) and the radius (r, distance from rotating axis). A standard centrifugal acceleration scale is gs, which is the ratio of the measured acceleration to the earth's acceleration due to gravity, g_c=9.80665 m/s^2. The manufacturer of the RC identifies this scale as the Relative Centrifugal Force (RCF). RCF or gs is defined as:

$$RCF = 1.118 r \left(\frac{RPM}{1000} \right)^2$$

RCF = Relative Centrifugal Force, gs.

r = radius [mm], distance from the center of spindle to the floor of the centrifuge container.

RPM = Rotations per minute, the rotational speed of the rotor.

NOTE: For derivation and equivalence of RCF and gs see Appendix A.

The inverse function that is used to calculate RPM given the RCF and radius is:

$$RPM = \sqrt{\frac{RCF}{r \times 1.118} \times 1000}$$

Each rotor is rated to a maximum rotational speed, which translates to a maximum RCF given the radius of rotation. An accidental setting of RPM to a value above the rotor rated value is not allowed due to a rotor identification system.

4.1.1 Rotor Identification

When the centrifuge starts spinning the rotor, it picks up the rotor identification with the aid of a sensor. The rotor identification is a 12 digit binary sequence. The controller looks up the speedometer code in a look-up table in memory. The table contains the maximum speed of the rotor, run up and braking ramps and control response of electronics. The control software will compare the set speed to the rated. If the set speed is greater than the maximum rated speed, the rotor will stop after a few revolutions and the correct rotor speed rating will be displayed. (i.e., 'R: 01 n_MAX=6000', rotor speed code number is 1 and the rotor max speed is 6000 RPM). The set speed will change to the maximum speed and the RC will be on standby mode.

If the rotor is unidentified due to the rotor identification not on the look-up list or there are no values for that speed code number, then the controller will utilize default values. The default max speed is 2000 RPM and the minimum speed is 1000 RPM.

4.2 CENTRIFUGAL FORCE

The rotors are designed to separate substances up to a maximum mean homogeneous density of 1.2 kg/dm^3 when rotating at the stated speed.

DANGER: Denser substances must be centrifuged at lower speed. The permissible speed can be calculated using the following formula:

$$Reduced\ Speed(n_{red}) = \sqrt{\frac{1.2}{GreaterDensity}} \times RatedSpeed$$

4.3 ANGULAR ACCELERATION

The operator shall consider the effects of the angular acceleration during spin-up and spin-down on the Spinning Elements. The angular acceleration, or the change in angular speed per unit time, can be selected for both spin-up and spin-down. For spin-up, the ramp levels are 1 through 9, with level nine being the greatest angular acceleration and achieving set speed in least amount of time. For spin-down (braking), the ramp levels are 0 through 9, with level nine being the greatest angular deceleration and stopping the rotor in least amount of time. During braking, the RC applies a varying amount of resistive load to the backwards-emf (electromagnetic force) of the rotor motor. At ramp-down level 0, no resistive load is applied and all braking of the free spinning rotor is due to air and mechanical friction losses. See Table 4.3-1.

Due to variability in parameters, only the minimum and maximum angular accelerations are presented to characterize the capabilities of the RC.

TABLE 4.3-1

Rotor	1020	1016	1158
Load condition	8 x 5 ml	6 x 50 ml	48 x micro rotor
Max RPM	5,000	6,000	14,000
Spin up time to 97% RPM at level 9	9 sec	20 sec	28 sec
Spin up time to 97% RPM at level 0	1 min 25 sec	2 min 54 sec	4 min 17 sec
Spin-down time at level 9	12 sec	24 sec	33 sec
Spin-down time at level 0	50 sec	6 min 44 sec	8 min 16 sec

4.4 SPINNING ELEMENT STRUCTURAL INTEGRITY

The Spinning Element shall sustain the induced force of the spinning element mass under specific centrifugal and angular acceleration without structural failure.

5.0 ENVIRONMENTAL CONDITIONS

5.1 SAMPLE CLEANLINESS

The external surfaces of the Spinning Element shall be cleaned prior to its installation into the RC. Cleanliness shall conform to a visibly clean level as specified in SN-C-0005, NSTS Contamination Control Requirements.

5.2 SAMPLE CONTAINMENT

The sample containers shall provide safe containment of any by-product of payload experiment - gaseous, liquid or solid. No toxic or any other gasses shall be discharged into the chamber.

NOTE: The RC provides ZERO level of containment for the Spinning Element.

5.3 ILLUMINATION

The user shall provide any special illumination.

6.0 THERMAL INTERFACE

6.1 CHAMBER ENVIRONMENTAL CONDITIONS

The Chamber Environmental Condition will vary as the cabin air except for temperature. See SSP 5700, Pressurized Payloads Interface Requirements Document, for details on cabin environment.

The temperature of the Chamber can be set to a temperature in the range of ambient to +4 °C with an uncertainty of +2 °C and -4 °C.

7.0 ELECTRICAL POWER INTERFACE

There are no power interfaces provided for users of the RC. For information regarding power interfaces to the EXpedite the PRocessing of Experiments to Space Station (EXPRESS) rack, reference LS-71078-1, Hardware Requirements Document (HRD) for the Human Research Facility Refrigerated Centrifuge.

8.0 DATA INTERFACE

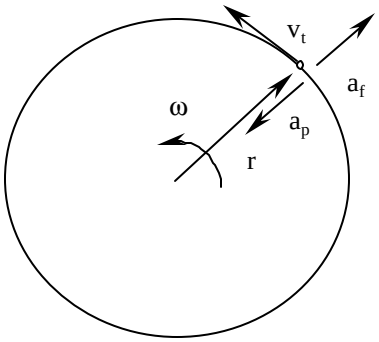
The RC does not provide a data interface to the user. The RC uses the HRF rack data services. The RC transmits data through a blind mate receptacle part number M83733/3RA131 with pin assignment as shown in Figure 8-1 and Table 8-1.

The RC does collect and transmit health and states data to the ground. For further definition of this feature, reference LS-71078-1, Hardware Requirements Document (HRD) for the Human Research Facility Refrigerated Centrifuge.

APPENDIX A

A point, rotating at a constant tangential velocity v_t, about an axis of rotation at a radius of r, experiences a centripetal acceleration a_p, which is equal in magnitude to the centrifugal reaction acceleration a_f:

$$a_f = -a_p = \frac{v_t^2}{r} \tag{1}$$



Recall,

$$v_t = 2\pi r w \tag{2}$$

where, ω is the rotational speed, in revolutions per second.

Substitute Eq. (2) into Eq. (1).

$$a_f = \frac{(2\pi r w)}{r} = (2\pi w)^2 r \tag{3}$$

Representing the centrifugal acceleration relative to the acceleration due to gravity we get gs:

$$gs = \frac{a_f}{g_c} = \frac{(2\pi w)^2 r}{g_c} = \frac{(2\pi)^2}{g_c} r w^2 \tag{4}$$

Fixing the units of ω, as RPM and r as mm,

$$gs = \frac{(2\pi)^2}{9.80665[m/s\text{^}2]} r[mm] \frac{1[m]}{1000[mm]} \left(w[rpm] \frac{1[\min]}{60[s]}\right)^2$$

$$gs = \frac{(2\pi)^2}{9.80665} r \frac{1}{1000} \left(w \frac{1}{60}\right)^2 = \frac{(2\pi)^2 1000}{9.80665} \left(\frac{1}{60}\right)^2 r \left(\frac{w}{1000}\right)^2$$

$$gs = 1.118 r \left(\frac{w}{1000}\right)^2 = RCF$$

Therefore, the manufacturer RCF is gs.

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